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Immigration of insects into bins storing newly harvested wheat on 12 Kansas farms

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Abstract

Adult insects entering 34 bins (36–238 t capacity) storing newly harvested hard red winter wheat on 12 farms in Kansas were sampled from July through December 1998 using ventilation traps. Insects moving through the grain stored in these bins were sampled using probe traps. During the fourth week of storage, probe traps captured *Cryptolestes ferrugineus* in all bins, *Ahasverus advena* in 32 bins, *Typhaea stercorea* in 31 bins, and *Rhyzopertha dominica* in 13 bins. Means \pm SE of 5.6 ± 0.7 *C. ferrugineus*, 0.5 ± 0.2 *R. dominica*, 3.5 ± 0.3 *A. advena*, and 3.5 ± 0.7 *T. stercorea* were caught per day in probe traps. Ventilation traps provided a more direct measure than probe traps of the total numbers of insects entering bins storing newly harvested wheat. Immigration of *A. advena* and *T. stercorea* increased more than that of other species during the storage period, exceeding that of *C. ferrugineus* and *R. dominica* during some weeks. *Rhyzopertha dominica* had the lowest immigration rate. Bin size did not influence ventilation trap catch but as many as a third more insects may immigrate into large bins at the eaves compared with small bins because of their larger circumference. The mean numbers of *C. ferrugineus*, *R. dominica*, *A. advena* and *T. stercorea* captured in ventilation traps at the bin cap were 7.8, 2.7, 15.1 and 18.3 times, respectively, those captured in ventilation traps at the bin eaves. The estimated means \pm SE for total numbers of insects entering a bin each day were 13.6 ± 4.2 *C. ferrugineus*, 6.3 ± 4.7 *R. dominica*, 5.8 ± 1.4 *A. advena*, and 21.9 ± 8.2 *T. stercorea*. Estimates of immigration rates can improve the accuracy with which insect densities are predicted using insect population growth models, and allow computer models to be used more effectively in managing insect pests. Insect infestations may be reduced by screening the openings between the bin cap and the roof, or the roof and the side walls. Published by Elsevier Science Ltd.

Keywords: Population monitoring; Insects; Trapping; Dispersal; Stored products

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1. Introduction

Flight activity of insects outside bins and their immigration into bins are important factors to consider in managing insect pests. Newly harvested wheat generally becomes infested after being stored in a bin (Hagstrum, 1989; Vela-Coiffier et al., 1997). Because the number of insects migrating into a bin influences the level of insect infestation, estimates of insect immigration rates are needed to accurately forecast insect infestation levels using computer models (Flinn et al., 1997).

The flight activity of stored-product insects outside bins has been studied fairly extensively. Baited (Cogburn et al., 1984; Hagstrum et al., 1995; Weston et al., 1997) and unbaited (Sinclair and Haddrell, 1985; Throne and Cline, 1989, 1994; Dowdy and McGaughey, 1994, 1998; Barney and Weston, 1996; Vela-Coiffier et al., 1997) sticky traps, food-bait traps (Throne and Cline, 1991), Lindgren multi-funnel traps baited with wheat or pheromone and wheat (Fields et al., 1993), a revolving insect trap (Schwitzgebel and Walkden, 1944), a truck trap (Sinclair and Haddrell, 1985) and Johnson–Taylor suction traps (White et al., 1995) have been used to monitor insect populations outside grain storage bins on farms, at elevators, or at greater distances from stored grain.

Immigration of these insects into grain storage bins has been studied using three types of traps. Barrer (1983) monitored insect immigration from February 1980 to January 1981 using eight traps installed in the plastic sheets covering each of four flat storages of wheat at two locations. The traps were tobacco tins with a small open hole in the lid and a larger screened hole in the bottom. The numbers of insects caught in traps were counted after 11 months. The rusty grain beetle, *Cryptolestes ferrugineus* (Stephens) was the dominant species but lesser grain borers, *Rhyzopertha dominica* (F.); foreign grain beetles, *Ahasverus advena* (Waltl); hairy fungus beetles, *Typhaea stercorea* (L.), and 13 other species were also caught. Schwitzgebel and Walkden (1944) used a galvanized sheet-metal cone with a quart jar attached to catch all of the insects entering through the roof vents of two bins storing wheat at one site during September, 1941 and April through October 1942. Between 8 July and 4 August 1942, they caught an average of 9.0 flat grain beetles, *Cryptolestes pusillus* (Schonherr); 0.4 *R. dominica*, 2.2 *A. advena* and 0.3 *T. stercorea* per day. Barney and Weston (1996) used yellow sticky traps that covered half of the roof vent openings of eight bins storing corn at one site from mid-May to mid-November 1992, April through October during 1993, and July to mid-October 1994. During each of 3 weeks, ≥ 50 Angoumois grain moths, *Sitotroga cerealella* (Olivier) were caught. Because many bins are ventilated through the gaps between the cap and roof of the bin, and the roof and the side wall of the bin rather than roof vents, information on immigration through these openings is needed.

The objectives of the current study were to estimate the numbers of insects entering grain bins through openings between the bin roof and the bin cap or the bin side wall and the roof, and to determine whether bin size influences insect immigration rate.

2. Materials and methods

The numbers of insects entering 34 bins (36–238 t storage capacity) storing newly harvested hard red winter wheat on 12 farms in Kansas were monitored at weekly intervals from July

through December 1998 (Table 1). Newly harvested wheat generally was stored between 12 and 26 July. Farms were designated by a letter, and each bin on a farm was assigned a number. Farms were located in Dickinson, Ellsworth, Marion, McPherson, Reno and Stafford Counties.

Traps were installed during the first week of storage. Eleven 45-cm-long probe traps (Storgard WB Probe II, Trece, Salinas, CA) were placed in each bin. Three probe traps were placed within 30 cm of the center. The other eight probe traps were placed at locations one-third and two-thirds

Table 1

Storage capacities of each bin, and probe trap catches per day of four insect species in wheat during the fourth week of storage^a

Bin ID	Bin capacity (t)	<i>Cryptolestes ferrugineus</i>		<i>Rhyzopertha dominica</i>		<i>Ahasverus advena</i>		<i>Typhaea stercorea</i>	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
A1	36	0.58d	0.29	0b	—	0.06d	0.03	0.03b	0.03
B1	41	0.21d	0.11	0b	—	0.17d	0.13	0.31b	0.11
C1	46	0.03d	0.02	0b	—	0.12d	0.04	0.09b	0.08
D1	49	0.03d	0.02	0b	—	0d	—	0.40b	0.23
B2	51	0.23d	0.07	0b	—	0.38d	0.10	0.27b	0.12
E1	68	0.05d	0.02	1.51b	0.61	0.01d	0.01	0b	—
C2	89	0.03d	0.02	0.03b	0.02	2.48d	0.47	0.48b	0.14
C3	89	0.18d	0.08	0.06b	0.03	11.55ab	2.30	0.68b	0.27
F1	95	5.99cd	2.03	0.12b	0.09	3.82d	1.32	1.77b	0.91
F2	95	1.83d	0.47	0b	—	3.90d	0.61	0.44b	0.14
G1	95	0.78d	0.22	0.03b	0.03	0.45d	0.19	0.45b	0.15
H1	95	1.71d	0.36	0b	—	5.78b	1.16	1.13b	0.54
G2	100	4.77cd	2.05	0.35b	0.16	5.90b	1.36	3.29b	1.28
A2	103	0.22d	0.07	0b	—	0.12d	0.04	0.21b	0.06
A3	103	0.31d	0.04	0b	—	0.25d	0.08	0.22b	0.09
I1	108	1.29d	0.62	0b	—	0.40d	0.11	0.14b	0.07
I2	108	2.30d	0.87	0.01b	0.01	2.04d	0.78	0.38b	0.36
I3	108	0.57d	0.27	0.04b	0.04	4.42c	1.30	0.83b	0.68
G3	122	30.01b	4.61	0.40b	0.22	11.19ab	1.78	12.58b	2.41
H2	122	46.30a	10.12	3.95a	1.88	3.55d	0.78	3.29b	0.76
H3	122	0.62d	0.28	0.16b	0.16	0.10d	0.06	0b	—
H4	122	2.95d	0.98	0b	—	1.75d	0.63	0.18b	0.10
H5	135	11.22cd	3.14	0.10	0.05	10.00abc	2.58	1.88b	0.74
J1	149	6.71cd	1.31	0.48	0.28	1.39d	0.44	4.73b	1.70
J2	149	8.44cd	1.60	0b	—	10.91abc	2.41	7.94b	1.88
K1	154	1.38d	0.50	0b	—	4.00d	0.64	0.48b	0.19
L1	154	19.55bc	5.14	0b	—	15.00a	1.41	39.73a	17.74
L2	154	0.45d	0.24	0b	—	0.39d	0.35	6.49b	3.84
M1	189	2.06d	0.71	0b	—	1.03d	0.17	0.53b	0.22
D2	189	0.04d	0.03	0b	—	0.03d	0.02	0.75b	0.30
D3	189	0.09d	0.03	0b	—	0.05d	0.03	0.99b	0.66
J3	203	13.38cd	3.89	0b	—	8.58abc	1.20	18.31b	5.49
G4	238	0.23d	0.10	0b	—	0.30d	0.06	0.55b	0.14
G5	238	0.13d	0.07	0b	—	0d	—	0b	—

^a Means ($n=11$) in each column followed by the same letter are not significantly different at the 1% level.

the distance between the center and bin wall in north, south, east and west compass directions. Two ventilation traps were placed at the cap, and two at the eaves except for six bins which were sealed at the eaves. Ventilation traps are 35-cm deep funnel-shaped cloth bags with the large ends attached to bins using magnets and an insect collection jars attached to the small ends. A funnel in the collection jar keeps insects from escaping. The large end of the trap covers a 40.6 cm section of the gap between the bin cap and the roof, or the roof and the side walls.

Grain temperatures were measured weekly at a depth of 25 cm below the grain surface in the center of each bin using a Digi-Sense thermistor reader (Model 8523, Cole-Parmer Instrument Co., Chicago, IL) with YSI series 400 thermistor probes (Yellow Springs Instrument, Yellow Springs, OH). Grain samples were taken from the center of each bin with a grain trier and moisture contents were determined in the laboratory with a moisture meter (Model GAC II, Dickey-John Corp., Auburn, IL). Differences between bins in grain temperature, grain moisture, and insect catch were analyzed using analysis of variance and Tukey's studentized range test (SAS Institute, 1990).

3. Results

3.1. Variation in insect density among bins

The numbers and species of insects caught in probe traps differed between bins and farms (Table 1). During the fourth week of storage, probe traps captured *C. ferrugineus* in all of the bins, *A. advena* in 32 bins, *T. stercorea* in 31 bins, and *R. dominica* in 13 bins. *Rhyzopertha dominica* was not found on farms A, B, D, K, L or M. Except for farm E, which had only one bin, *R. dominica* also was not found in all of the bins on any of the other farms. Means \pm SE of 5.6 ± 0.7 *C. ferrugineus*, 0.5 ± 0.2 *R. dominica*, 3.5 ± 0.3 *A. advena* and 3.5 ± 0.7 *T. stercorea* were caught per day in probe traps. Differences between bins in the numbers of insects caught in probe traps were significant for *C. ferrugineus* ($F=15.40$, $df = 33, 351$; $P < 0.01$), *R. dominica* ($F=4.21$; $df=33, 351$; $P < 0.01$), *A. advena* ($F=15.53$; $df=33, 351$; $P < 0.01$), and *T. stercorea* ($F=5.27$; $df=33, 351$; $P < 0.01$). Only one bin had significantly higher *T. stercorea*. Farms G and H had bins with some of the highest and the lowest insect infestation levels. The numbers of adult insects captured by probe traps in newly harvested wheat after 4 weeks of storage provide a measure of the numbers of insects immigrating into these bins because their offspring have not had time to complete development.

3.2. Seasonal variation in immigration

The mean numbers of *C. ferrugineus* and *T. stercorea* caught in ventilation traps were highest after 7 weeks of storage (September), *A. advena* after 9 weeks (late September or early October), and *R. dominica* after 11 weeks (October), and then the numbers of each species entering bins tended to decrease (Fig. 1). Between the third and the eighth week of storage, the numbers of *T. stercorea* entering bins exceeded the numbers of other species. Between the seventh and the ninth week of storage, the numbers of *A. advena* entering bins exceeded the numbers of

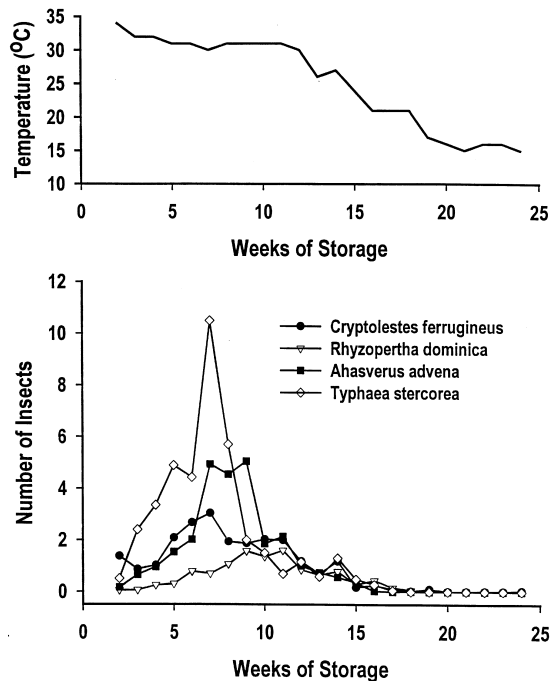


Fig. 1. Mean grain temperatures and mean ventilation trap catches per day of four species at the cap of bins for each week of storage period.

C. ferrugineus and *R. dominica*. The immigration of all species was very low after 19 weeks when grain temperatures dropped below 20°C.

3.3. Effect of bin size on immigration

Ventilation trap catches of *C. ferrugineus* ($F=1.99$; $df=4, 77$; $P=0.10$) and *R. dominica* ($F=1.56$; $df=4, 77$; $P=0.19$) did not differ significantly with the storage capacity of bins (Table 2). For *A. advena* ($F=3.64$; $df=4, 77$; $P<0.01$) and *T. stercorea* ($F=9.58$; $df=4, 77$; $P<0.01$), the numbers of insects caught entering bins of 136–162 t capacities were significantly higher than those entering other bins because large numbers of insects entered a few bins. Means \pm SE of 1.0 ± 0.3 *C. ferrugineus*, 0.3 ± 0.2 *R. dominica*, 0.7 ± 0.2 *A. advena*, and 2.3 ± 0.7 *T. stercorea* were caught per day in ventilation traps at the bin cap. Grain moisture ($F=2.12$; $df=4, 77$; $P=0.09$) and temperature ($F=1.00$; $df=4, 77$; $P=0.42$) did not differ significantly with bin capacity.

3.4. Entry point of immigrants

The average numbers of insects caught in a ventilation trap located at the bin eaves (Table 3) were generally lower than the average numbers caught in a ventilation trap located at the bin cap (Table 2). However, the 40.6 cm long ventilation traps covered 11–23% of the circumference at the cap but only 1.8–3.0% of the bin circumference at the eaves. Means \pm SE of 0.128 ± 0.037 *C. ferrugineus*, 0.128 ± 0.068 *R. dominica*, 0.043 ± 0.024 *A. advena*, and 0.126 ± 0.109 *T. stercorea*

Table 2

Effect of bin storage capacity on average numbers of insects caught per day in ventilation traps located at cap of bin during the first 4 weeks of storage^a

Bin capacity (t)	<i>n</i>	Moisture content (%)		Temperature (°C)		<i>Cryptolestes ferrugineus</i>		<i>Rhyzopertha dominica</i>		<i>Ahasverus advena</i>		<i>Typhaea stercorea</i>	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
27–81	6	11.3a	0.3	32.4a	0.6	0.16a	0.05	0.58a	0.45	0.03a	0.02	0.12b	0.06
82–108	9	11.0a	0.5	32.2a	0.4	0.81a	0.45	0.08a	0.03	0.73ab	0.26	1.04b	0.52
109–135	7	11.1a	0.5	30.0a	2.6	1.93a	0.94	0.02a	0.01	0.42ab	0.22	0.37b	0.17
136–162	6	12.0a	0.7	34.7a	1.5	1.91a	0.46	0.10a	0.05	1.96b	0.82	10.99a	3.50
163–238	6	11.9a	0.3	31.3a	1.1	0.34a	0.11	0a	—	0.46ab	0.26	2.52b	1.69

^a Means in each column followed by the same letter are not significantly different at the 1% level.

Table 3

Effect of bin storage capacity on average numbers of insects caught per day in ventilation traps located at eaves of bin during the first 4 weeks of storage^a

Bin capacity (t)	n	<i>Cryptolestes ferrugineus</i>		<i>Rhyzopertha dominica</i>		<i>Ahasverus advena</i>		<i>Typhaea stercorea</i>	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE
27–81	4	0.071	0.044	0.253	0.160	0	—	0	—
82–108	6	0.036	0.015	0	—	0	—	0.013	0.013
109–135	6	0.186	0.086	0.062	0.057	0.124	0.100	0.500	0.485
136–162	6	0.214	0.180	0	—	0.026	0.017	0.032	0.020
163–238	6	0.148	0.035	0	—	0.051	0.029	0.026	0.021

^a Means in each column are not significantly different at the 1% level.

were caught per day in ventilation traps at the eaves. The numbers of *C. ferrugineus* ($F=0.86$; $df=4, 62$; $P=0.50$), *R. dominica* ($F=2.47$; $df=4, 62$; $P=0.05$), *A. advena* ($F=1.03$; $df=4, 62$; $P=0.40$), and *T. stercorea* ($F=0.85$; $df=4, 62$; $P=0.50$) caught entering bins at the eaves did not differ significantly with bin capacity.

4. Discussion

Stored-product insects generally do not infest wheat in the field in Kansas (Hagstrum, 1989) and Oklahoma (Vela-Coiffier et al., 1997) but infest newly harvested grain soon after it is stored. The numbers of insects captured in probe traps during the fourth week of storage can provide an estimate of the numbers of insects infesting newly harvested wheat. As in previous studies (Hagstrum et al., 1996), differences in the level of insect infestation between bins on the same farm were as great as differences between bins on different farms. Probe trap catches can be converted to absolute densities per 0.5 kg of wheat using equations from Hagstrum et al. (1998). These estimated mean absolute densities per 0.5 kg of wheat in the current study were 0.075 *C. ferrugineus*, 0.145 *R. dominica*, 0.100 *A. advena* and 0.052 *T. stercorea*. Although initial insect infestation levels were low, populations can grow exponentially at a rate of 10-fold per generation and soon reach damaging levels (Hagstrum, 1996).

Insects entering 34 bins storing newly harvested wheat on 12 farms in Kansas through the gaps between the cap and the roof or the roof and the bin walls were sampled in the current study. Insects entering bins storing corn (Barney and Weston, 1996) or carryover wheat (Schwitzgebel and Walkden, 1944) through the roof vents had been sampled at single sites and those entering flat storages of wheat through openings in the plastic cover (Barrer, 1983) had been sampled at two sites. The numbers of insects caught entering bins in the current study varied between bins and insect species, and during the storage period. *Rhyzopertha dominica* had the lowest immigration rate. Immigration rates of *A. advena* and *T. stercorea* increased more than those of other species during the storage period, exceeding those of *C. ferrugineus* and *R. dominica* during some weeks. Bin size did not influence ventilation trap catch but as many as a third more insects may enter large bins at the eaves compared with small bins because of their larger circumference. Immigration of insects into bins declined before grain temperature began to decrease because grain temperatures generally lag behind air temperatures (Hagstrum, 1987).

The mean numbers of *C. ferrugineus*, *R. dominica*, *A. advena*, and *T. stercorea* captured in ventilation traps at the bin cap were 7.8, 2.7, 15.1, and 18.3 times, respectively, those captured in ventilation traps at the bin eaves. In an earlier study, sticky traps near the bin cap caught 4.7–14.2 times more insects than those near the eaves (Hagstrum et al., 1994). The larger numbers captured at the cap than at the eaves could be due to insects being attracted to wheat odor carried out of the bin by hot air rising as the bin head space heats during the day. Alternatively, insects encountering the bin roof may land, walk up the roof to the cap and enter the bin.

Ventilation traps provide a more direct measure than probe traps of the total numbers of insects entering bins storing newly harvested wheat. Using the percentages of the cap and bin circumferences covered by a ventilation trap and assuming equal immigration from all directions, the total numbers of each insect species entering a bin each day can be estimated. The estimated means \pm SE for total numbers of insects entering a bin each day were 13.6 ± 4.2 *C. ferrugineus*, 6.3 ± 4.7 *R. dominica*, 5.8 ± 1.4 *A. advena*, and 21.9 ± 8.2 *T. stercorea*. Insects initially infest a few hundred kilograms of wheat near the surface but eventually move down into the grain mass and infest thousands of kilograms (Hagstrum, 1989). Over an insect generation time of approximately 30 days, these insect immigration rates could result in insect densities per 2727 kg (100 bushels) of 0.076 *C. ferrugineus*, 0.035 *R. dominica*, 0.032 *A. advena*, and 0.121 *T. stercorea* which are similar to insect densities estimated using probe traps. Once immigrants begin to reproduce in a bin their offspring are likely to greatly outnumber the new immigrants entering a bin (Hagstrum, 1987).

The current study measures the rate of insect immigration into bins storing newly harvested wheat and provides estimates of the variability in insect immigration rates between bins and farms. Although more insects migrate into large bins at the eaves compared with small bins because of their larger diameter, the differences in insect immigration rates due to bin size are small because more insects migrate into a bin at the cap than at the eaves. Estimates of insect immigration rates from the current study can improve the accuracy with which insect densities are predicted using insect population growth models, and allow computer models to be used more effectively in managing insect pests. Insect infestations may be reduced by screening the openings between the bin cap and the roof, or the roof and the side walls.

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